with a truncated version. Indeed, in yield terms, a three-basis-point difference between the high and low price at a Treasury auction would be considered large. With such a small spread, the revenue from price discrimination is correspondingly small. Accordingly, a small increase in demand in the shift to an auction format less conducive to bid shading could easily overwhelm the loss in revenue from price discrimination. Formally, these two areas depend on the extent of the shift in demand, the elasticity of that demand, and the maximum price range shown to the Treasury. In general, an inelastic demand schedule with a wide price range would have to shift by a large amount to offset the revenue from ending price discrimination.

Support for Friedman's argument is stronger than the balancing of these welfare triangles would suggest. Those analysts working with explicit models of bidder behavior in a Treasury-like setup, rather than reduced-form demand schedules, typically find that a second-price scheme does produce higher revenue for the seller.[22] Further, in 1962, Friedman made a persuasive argument that revenue would increase.[23] Dealers devote considerable energies to the auction only to sell those securities almost immediately to customers

22. Early support for Friedman's contention can be found in Vernon L. Smith, "Bidding Theory and the Treasury Bill Auction: Does Price Discrimination Increase Bill Prices?" *Review of Economics and Statistics* vol. 48, 1966, pp. 141-146. Exact conditions under which revenue increases a model close to current practice are given in Sushil Bikhchandari and Chi-Fu Huang, "Auctions with Resale Markets" An Exploratory Model of Treasury Bill Markets," *The Review of Financial Studies* vol. 2, 1989, pp. 311-339. Also see Theorem 4 in Robert J. Weber, "Multiple-Object Auctions," in Richard Englebrecht-Wiggans, Martin Shubik, and Robert M. Stark, editors, *Auctions, Bidding, and Contracting: Uses and Theory* (New York: New York University Press), 1983, pp. 165-191. However, this result requires that auction participants be risk neutral. Some element of risk aversion in a common-values model of bidding renders the revenue rankings ambiguous. See Milgrom and Weber, op. cit., p. 1114.

23. From correspondence quoted in Goldstein, op. cit.

--and most profit from doing so. Part of those resources devoted to that distribution could be appropriated by the Treasury if it could directly deal with those customers. A second-price auction, since it is less penalizing to the aggressive or uninformed, may be the best vehicle to attract those people.

VI. Evidence on Auctions

The empirical evidence on auctions falls into two categories: what people do and what academics write about. Auction practices vary, with the private exchange of goods tending to be made by open outcry, while governments rely mainly on sealed bids. Where government securities are involved, those sealed bids may determine the prices of the awards (as in the discriminating auctions of the United States, Japan, and, for long-term debt, of Germany) or awards may be made at one price (as in the United Kingdom).[24] On the other hand, the private exchange of financial instruments, whether on the floors of stock exchanges in New York or the in the trading pits in Chicago, more closely resembles an ascending-price open-outcry auction. The academic evidence on auctions involves: performing experiments, where mock auctions are conducted in laboratory settings: measuring comparative performance by valuing the revenue differentials on those relatively rare instances where auctions differed by only one or two attributes; and looking for the price differentials predicted by the presence of market power among auctioned and secondary-market securities.

Experimental Economics. Auctioning represents one of the few aspects of theory that can be tested by controlled experiment. All

24. A survey of auction technique in the industrial countries is provided in the *Joint Report on the Government Securities Market*. ibid., pp. B2-B40.

that is needed is initial funding, a room, a group of participants (usually students), and an item to be put on the block. By varying the setup of the auction in repeated trials with new subjects, the investigator can make some assertion about how bidding works and the optimal arrangement of auctions. For example, Kagel et al. find strong evidence of an ex post winner's curse early in multiple period trials--that is, the early winners of sealed-bid auctions significantly overbid.[25] Only over time did the participants sufficiently shade their bid to the market consensus. Taken literally, the repeated failure to properly condition bids in a first-price auction implies that the demand-shift effect of a switch to a second-price auction would be modest; hence, under the Friedman scheme, the revenue gained by the change in demand might not offset the loss from the inability to discriminate by price.

Unfortunately, these experiments are joint tests, depending on auction technique and the ability of agents to make rational forecasts and to learn, as well as the extent of their risk aversion. The failure to shade bid, for example, may speak more to undergraduates' understanding of the auction setup than to any aspect of security dealers' behavior. Indeed, with the profit motive so sharply refined in the investment community, it appears that the laboratory setting of the work on experimental auctions may not be particularly relevant.

Relative Auction Performance. There have been three major experiments with sealed-bid auctions in a financial setting: In 1973 and 1974, the U.S. Treasury departed from its usual practice to sell

25. John H. Kagel, Dan Levin, Raymond C. Battalio, and Donald J. Meyer, "First-Price Common Value Auctions: Bidder Behavior and the 'Winner's Curse,'" *Economic Inquiry* vol. 27, April 1989, pp. 241-258.

long-term bonds under a uniform second-price arrangement; from 1976 to 1980, auctions conducted by the International Monetary Fund to sell part of its gold stock were split between discriminating first-price and uniform second-price setups; and commencing 1990, the Mexican government moved to uniform price awards in selling its debt. These experiments provide mixed evidence as to the relative merits of auction technique. There is little hard evidence that auction form mattered in the first two cases. On the other hand, the Mexican experience, as interpreted by Steven Umlauf, offers strong support for bidding theory.[26] Umlauf found that the switch to uniform price awards significantly shaved the profits of dealer intermediaries.

Other tests of auction technique move outside financial markets, making it harder to apply the common-values assumption natural to Treasury auctions. The most investigated episode involves the sale of timber contracts by the U.S. Forest Service in 1977, when due to a change in federal law about 250 were sold in ascending-price open-outcry auctions and nearly 400 by first-price sealed-bid auctions. Again, the evidence appears mixed, apparently depending on the formal assumptions of the statistical model and estimation technique. The weight of the evidence suggests that revenue is about equal across auction technique, perhaps favoring sealed-bid auctions.[27]

Relative Price Effects. An alternative approach is to look for the consequences of strategic behavior in relative prices.

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26. Steven R. Umlauf, "An Empirical Study of the Mexican T-Bill Auction," Working paper, London Business School, October 1991.

27. Robert G. Hansen provides a brief review of this evidence, concluding that "anyone with strong revenue equivalence priors should not be shaken," p. 157 in "Empirical Testing of Auction Theory," *American Economic Review* vol. 75, May 1985, pp. 156-159.

Returning to our three-panel determination of Treasury prices (Figure 8), the bid shading in response to the winner's curse should lower the auction price of a security relative to where it trades in the when-issued and secondary markets. In recent papers, Elizabeth Cammack and David Simon perform pairwise comparisons of these markets to test bidding theory.[28]

In the two rightmost panels of Figure 8, the difference between the auction and secondary-market prices reflects the return to dealers for their services, or, in Friedman's terms, the resources lost by an inefficient auction mechanism. Elizabeth Cammack's analysis of Treasury bill auctions measures this effect, showing that over the period from 1973 to 1984 that "the mean auction price for the 91-day bill is about four basis points less than the mean secondary market price for the same bill traded on the day of the auction and day after the auction."[29] The following table updates the Cammack results using information on the auctions of three-month, six-month, and one-year bills since 1979. Column 1 gives the average auction rate for these bills over different periods, while the next column presents the rates that prevailed in secondary market trading for similar securities at the end of the day. Column 3 gives the mean rates in the next day's trading of the auctioned securities. As is clear in the next two columns, across these bills and over different periods, auction rates do tend to be higher than those observed in

28. Elizabeth B. Cammack, "Evidence of Bidding Strategies and the Information in Treasury Bill Auctions," *Journal of Political Economy* vol. 99, February 1991, pp. 100-130, and David P. Simon, "Underwriting Premiums at Treasury Coupon Auctions: Evidence from Intraday Quotes," Working paper, Board of Governors of the Federal Reserve System, January 1992.

29. "Evidence on Bidding Strategies and the Information in Treasury Bill Auctions," *Journal of Political Economy* vol. 99, February 1991, pp. 105.

Table 1

Average Treasury Bill Rates

on a bank discount basis over selected periods

	---Close on:----					
	at Auction (1)	Auction Day (2)	Next Day (3)	Auction less: market rate (1)-(2)	(1)-(3)	Number of Auctions
	---------percent--------			--basis points--		
<u>January 1990 to August 1991</u>						
Three-month	6.70	6.66	6.59	4	11	88
Six-month	6.72	6.68	6.61	4	11	88
One-year	6.70	6.68	6.62	2	8	22
<u>November 1982 to December 1989</u>						
Three-month	7.47	7.43	7.45	4	2	378
Six-month	7.62	7.58	7.60	4	2	376
One-year	7.76	7.72	7.73	4	3	95
<u>October 1979 to October 1982</u>						
Three-month	13.08	13.04	13.03	4	5	678
Six-month	13.09	13.13	13.06	-4	3	678
One-year	12.78	12.67	12.58	11	20	128

secondary trading.[30] That is, winners of awards at auctions would reliably profit, on average, in the quick resale of the security, supporting Friedman's assertion that the Treasury loses under the current procedure.

To those familiar with the literature on corporate finance, Cammack's result may not be surprising. It is a well-established regularity that at initial offering, a security's price tends to be below that at which it subsequently trades. This underpricing of new issues holds for both initial public offerings and seasoned issues.[31] It may be that informational considerations and strategic behavior (of the limited number of buyers at Treasury auctions or the few members of the underwriting syndicate in IPOs) depress the primary relative to the secondary market price. Or it could be that we do not understand how those two markets are related.

For example, other considerations could cloud any inference taken from the table. Cammack's analysis is a literal translation of Friedman's implicit model of the Treasury market. Any difference between primary and secondary market prices is taken as evidence of market power, not the result of inherent differences between those two markets. However, factors such as quantity uncertainty, the fixed cost of bidding, and regulation could well pull the auction demand

30. These, as Cammack notes at length, are imperfect comparisons. The quotes in columns 1 and 2 do not precisely match up: The closing quote on auction day is from the previously auctioned bill, so it has a slightly shorter maturity than the bill in column 1. The quote in column 3 is from trading of the auctioned bill, but taken the next day, allowing other events, unrelated to the auction, to add noise to the relationship. In a period in which rates are trending up, for instance, one might expect a small positive gap between quotes on successive days.

31. For a summary, see Clifford W. Smith, Jr., "Investment Banking and the Capital Acquisition Process," *Journal of Financial Economics* vol. 15, 1986, pp. 3-29, particularly pp. 19-23.

schedule inward, independent of strategic behavior. Hence, the comparisons in the table, as well as Cammack's analysis, may overstate the cost of the current setup. Additionally, the membership of the inner ring of bidders at auctions--the primary dealers--has varied over the years, belying the assertion that they reliably profit from auctions.[32]

In recent work, David Simon has shifted the focus by comparing prices in when-issued trading relative to the auction--that is, he compares the two leftmost panels of Figure 8. Examining 66 Treasury coupon auctions in 1990 and 1991, he finds that, on average, a purchaser receives 3/4 basis point (in yield terms) more for securities purchased at the auction relative to those purchased at about the same time in the when-issued market. Thus according to Simon, the Treasury pays about 3/4 basis point to compensate for the quantity uncertainty implied by auction format.

VII. Arguments for the Present System

While the academic literature suggests that the current Treasury procedure has serious drawbacks, there are other considerations that do not fit nicely into theoretical models. The Treasury is obliged to provide easy entry into the auctions, broadening, where possible, the ownership of the public debt, and must closely hew to a crowded schedule of borrowing. Also, while the Treasury may not always get top dollar for its issues, the present auction system may make it easier to conduct monetary policy and ensure a deep and active secondary market in government obligations.

Keeping auctions accessible. The American tradition of equal access mandates that auctions be open to all interested parties

32. From a peak of 46 in 1988, there are now 38 primary dealers.

Consider Abraham Lincoln's view of the national debt at the end of 1864:

> Held as it is, for the most part, by our own people, it has become a substantial branch on national, though private, property. For obvious reasons, the more nearly this property can be distributed among all the people the better. . . . Men readily perceive that they cannot be much oppressed by a debt which they owe to themselves.[33]

Thus, the Treasury maintains a relatively decentralized distribution network, feeding through the Reserve Banks and their branches, when the bulk of its securities are sold in New York. Indeed, before the accumulation of technological advances, this network necessitated a sealed-bid setup, for how else could an investor in San Francisco reliably have equal standing to his New York brethren? Less than thirty years ago bids were compiled overnight and awards were announced the day following the auction. Today, however, technology can surely link bidders together without slips of paper in between, so that the choice of auction system can be driven by the criterion of efficiency.

Ensuring the Placement of Every Issue. Unlike private and most municipal issuers, the Treasury has only limited discretion in the timing of auctions. Borrowing needs are large and necessary for the continued operation of the government. As a result, most of the academic literature on the optimal organization of an auction does not apply. Those theoretical models posit a supplier willing to set a high reservation price--a floor on bidding--to extract higher

33. *Speeches and Writings, 1859-1865*, The Library of America, New York, 1989, pp. 651-652.

revenues. If that reservation price is not met or bettered in bidding, the auction is called off.

The Treasury, however, cannot call off an auction, but, rather, must take pains to make every one a success. While current procedures, on average, may concentrate bidding to a narrow group of dealers, their existence ensures a cadre of participants at every auction.[34] However, the value of that ready demand should not be overstated. Dealers will pay only a price at an auction that they think profitable, and ultimately the level of Treasury interest rates must make investors willing to hold the huge outstanding stock of U.S. debt.

Making Monetary Policy Easier. The first-price nature of Treasury auctions may narrow bidding and result in more resources being devoted to distributing Treasury securities than other arrangements. However, that means that the day-to-day implementation of monetary policy may be made easier. First, by concentrating information, discussions with a handful of key players can let Federal Reserve officials get the "tone and feel" of the market. Second, firms may willingly bear the obligations of primary dealership with regards to monetary policy (including reporting and actively participating in open market operations) in order to benefit at auctions. Third, the two-step distribution of Treasury securities means that, on average, dealers will hold large inventories of

34. Presence at each auction is an important standard for primary dealers: "In evaluating participation in Treasury auctions, the Fed will expect a dealer to bid in reasonable relationship to that dealer's scale of operations relative to the market, and in reasonable price relationship to the range of bidding by other auction participants." Quoted from *Joint Report on the Government Securities Market*, op. cit., p. E-4.

securities, which may make temporary open market operations (repurchase and matched-sale-purchase arrangements) easier to conduct.

Subsidizing secondary-market trading. If dealers profit in the distribution of auctioned securities, then they have a reason and the funds to promote an active secondary market in Treasury securities. As a by-product, quotes in this market can serve as the touchstone for other types of trading. Receiving too low a price for an auctioned security may be the Treasury's payment for these wider macroeconomic benefits.

VII. An Alternative Proposal

The Friedman proposal likely represents an improvement on current Treasury practice; however, it might not deter firms from the very behavior that called current practice into question. Collusive behavior relies on the closed nature of sealed bids--whether as the Treasury does it now or in a Friedmanite future. A schemer only needs to beat the market's best guess formed at 12:59:59 p.m. and leave his or her competitors no chance to react.

An open-outcry system lets other market participants react to any surprise. Technologically, there is no need to rely on pieces of paper to express the intent to purchase Treasury securities. Suppose that registered dealers could connect by phone (with appropriately designed security) to a central computer. Those not pre-registered could appear at their local Reserve Bank with sufficient documentation to be included as a serious bidder. The auction commences as the Treasury calls out a price and all interested parties submit their quantity demanded. With quick tabulation, the volume of bids at that price is announced and, in successive rounds, the price is raised until the volume demanded is smaller than the size of the issuance. The next-to-last price called out clears the auction market, since it

is the highest price consistent with selling the entire issue. Everyone who bid at the top price would be guaranteed awards at the lower, market-clearing price. Those who bid at the next-to-last price but who did not move up into the top group would receive the remaining securities at that lower price. Since bids from that group exceed the remaining securities, some scheme for partial awards would be required. For example, partial awards to that group could go to those who were timed as the earliest bidders or could be parcelled out on a prorated basis.

Strategically, a dealer attempting to corner this auction must show his or her hand to the competition, continually bidding in size as the Treasury auctioneer raises the price. This allows those outside the pool--particularly those short the when-issued security--to bid along with the colluders, narrowing the potential for profit in a corner attempt. To the extent that the average issuing price is raised in the attempt, the Treasury garners part of the profits. By way of contrast, in a sealed-bid auction, the bulk of the price action comes at the announcement of surprising awards, when other dealers realize that they are short and react. In a real-time auction, that reaction occurs when the bidding is still going on. Also, the positive information revealed by auction format, on average, should benefit Treasury revenue.

A real-time auction may pose a daunting technical challenge. The goal of equal access requires that every effort be made to decentralize the system: Anyone willing to pay the fixed cost of a properly configured terminal should be allowed to enter. At the same time, each bidder will need to be screened to assure payment if their bid is successful. If the fixed cost of entry is too large, then participation at the auction will be limited, perhaps perpetuating a

two-tiered distribution of securities and all the attendant risks. If access is too free, then the physical demands of directing a large volume of messages in a narrow span of time may prove taxing. The private sector provides some precedent, but those efforts are small relative to that envisioned here.

Opening the auction does not preclude market manipulation and, indeed, might create new opportunities for large traders. For example, the surprising presence of a large trader elevating demand during the early stages of an auction might lead to a groundswell of enthusiasm that pushed the market-clearing price above fundamentals.[35] Similarly, the sudden dropping out by a large trader at a low price might dampen spirits enough to lower the market-clearing price. Either might present the potential for profit. Also, as long as the three trading fora in Treasury securities are not perfectly integrated, the possibility of a market squeeze remains. At the least, an open-outcry auction does not abet a squeeze attempt by making it easy to bid away securities by surprise, as occurs in a sealed-bid auction--making it less likely that the Treasury would be the conterparty from which a manipulator amassed a controlling position. Further, with easy entry, larger traders would be pitted against each other in their pursuit of trading profits, as an open-outcry system turns market forces against market manipulation. Even if cornering is a small risk once the larger step toward efficiency of common pricing is taken, it is a grave risk, as a repeat of recent experience would call many aspects of the government securities market into question. As an added benefit, the technical sophistication required to conduct an automated open-outcry system also could be mar-

35. See the description of the "herd effect" in Gastineau and Jarrow, op. cit., p. 42.

available for compliance surveillance and monetary policy's open market operations.

VIII. Conclusion

The academic literature does not readily identify the best way to auction Treasury securities. While individual elements of the problem are addressed, many of the particular attributes of the trading in Treasury securities are not modelled. And what is individually modelled may interact in larger systems. The Friedman proposal does correct an obvious problem with the current technique, but it may not rule out repeating our recent experience. No matter how rigid the enforcement of the rules, the incentive remains for a rogue with capital to attempt to manipulate the market.

My subjective reading of the literature suggests that the optimal Treasury auction would have the following attributes, listed in order of importance:

- Second price. By awarding all securities at the lowest price of an accepted bid, investors wary of the winner's curse might directly enter the auction. This raises total demand, since bidders no longer feel as obligated to shade their bids. Also, by making direct bidding more attractive, individual dealers no longer have as much access to customer business in attempts to swing the market.
- Real time. Auctions involving many participants that are conducted on an open-outcry basis are less susceptible to corners, which rely on surprise. In a sealed-bid auction, that only requires shading above the market consensus. That surprise is lost if market participants can react during the bidding.

- Ascending price. If the auctioneer calls out an ascending list of prices until the issue is sold, then the surprise of a cornering attempt is further eroded. Simply, other bidders can follow the price up. Also, an ascending-price auction produces the highest expected revenue to the seller.

This proposal is not too far different from Friedman's, sharing a second-price award system to boost demand and raise revenue, but it does advocate the open outcry of bids. This extra step beyond Friedman's proposal is a form of insurance against the most serious threat to the integrity of trading: An auction in real time makes active manipulation more difficult. As a side benefit, an open-outcry auction returns some of the potential profit from collusion to the Treasury in the form of higher prices.

It must be emphasized that there are no guarantees. The large academic literature on auction theory does not provide a definitive answer to how best to auction Treasury securities. Any new system should be flexible enough to permit experimentation with auction design. Planning for an open-outcry system would provide the requisite flexibility.

Further, there are potential problems in a transition to a new auction system, as any reform likely would be designed to entice investors to bid directly. Investors, however, may be hesitant to step in at first, preferring to observe before acting, especially if there is a substantial fixed cost to bidding. In that interim, the dealers would be relied on for their usual role--taking down a hefty share of issuance--even though the reforms ultimately would erode their customer base and lessen their market power. One could imagine that dealers could threaten such a change in the system by either boycotting the auction or submitting off-market bids. Such actions.

however, would be tempered by the scores of price-sensitive investors in the Treasury market who might step in should auction prices differ markedly from those in secondary trading. Indeed, the threat of potential entry by itself might be sufficient to narrow the risk of an adverse reaction.

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